Optimising the delivery and pick-up routes for packed water bottles

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Abstract. This paper proposes an optimal solution for optimizing the route in delivery and pick-up paths from the manufacturer (depot) to the customers using packed water bottles as the case study. The model of packed water bottles' traveling routes with simultaneous delivery and pick-up will be generated to represent the mathematical model of the forward and reverse logistic. The objective function of the model is to minimize the transportation cost using a Tabu search. The output of the study will be a minimum transportation cost in serving the entire customer along the paths. To make the problem real, a case study will be undertaken in Southern Jakarta where a seller wants to distribute bottled water to its customers scattered around the city.

Keywords. Reverse logistic, vehicle routing problem, simultaneous delivery and pick up.

1. Introduction

Reverse logistics has shown tremendous growth over the last thirty years. Reverse Logistics (RL) is defined as a process of planning, implementing and controlling backward flows of raw materials, in process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal [1]. This recovery idea provides an opportunity for companies to differentiate or distinguish themselves relatively from a new perspective [2]. For example, Panasonic Europe claimed saving as much as 15 percent annually in recycling costs to fulfil a European Union waste requirement when the company decided to implement reuse over typical waste [3]. Furthermore, new alternatives are available to treat what in the past has been assumed as of no-value to become valuable. For example, a typical product gives its manufacturer an alternative to re-use its package instead of producing a new one. Moreover, according to Daniel [4] the volume and monetary value of products flowing in the reverse direction within the supply chain will continue to steadily increase as environmental, legal and customer service requirements increase throughout industries. This provides an explanation that RL will remain the positive trend in the future.

In practice, characteristic products and route assignment are two key developments in RL. According to Dethloff [5], because of a tendency of some products to use refillable packaging, manufacturers are expected to shift their focus to how the packages are sent back for reloading at minimum cost instead of producing a new one. In addition, to emphasize the importance of the product characteristics, De Brito [6] states "it is a challenging task to describe the current state of recovery for each of these product categories and identify for each the most appropriate reverse logistics chain and

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recovery". This indicates that reverse logistics in practice needs to be clear in terms of the characteristics of the product. Moreover, there is an economical consideration in terms of resending the packages. This suggests that RL requires a logical reason to assign the route to produce the shortest path as well as to minimise the cost in practice.

2. Literature Review

Reverse Logistics has been considered more seriously recently, both for academic and practical purposes, mainly for two reasons: economic interest and compliance to environmental regulations. Recapturing value, even in the end of life product, could become an economic trigger. Human responsibility to keep sustainability of this nature, to be inherited from generation to generation, might be another reason behind the regulation. In implementing reverse logistics, a company needs to consider a very important question: how to do it effectively and efficiently? Effectiveness could refer to minimizing cost while efficiency could refer to the right handling and scheduling. There are at least two keys needed to address the question in assigning the collection points and optimizing the route across the points. The collection points must ensure that all areas of the RL are covered as well as optimizing the route as much as possible.

2.1. Reverse Logistic

Figure 1 visualizes that the flow of the material in RL begins from the customer. The challenge is how to return the product from the customer to the manufacturer with the minimum cost and in the right time and the best condition. Achilas, et al. [7] propose a formula to optimize a reverse logistic model for electric and electronic equipment. This study modelled the electric and electronic waste route from 37 different collection points. It can be seen that the focus is on the transportation cost throughout the network. The authors claimed that their model approach to RL to minimize cost is broader compared to the previous studies since they consider the RL in four stages of the recycling process: collection sites, disassembly sites, treatment sites (recycling facility and repair facility) and final sites (disposal facility, secondary market, primary market).

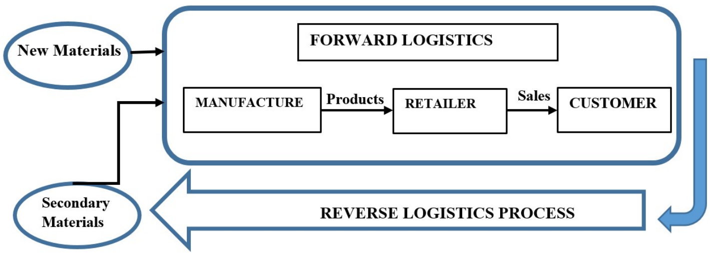
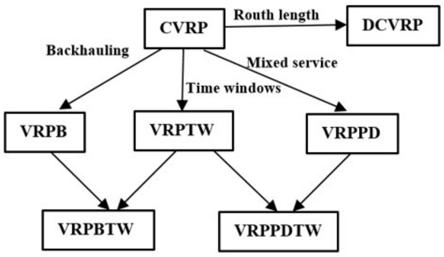


Figure 1. Logistics process. Source: Silva et al. (2013) [8]

2.2. Vehicle Routing Problem with Simultaneously Delivery and Pick-up (VRPSDP)

According to Toth and Vigo [9], the problems of VRP are divided into two main areas, capacitate and distance. The Capacitated VRP is the more studied recently and has many variants, as shown in Fig 2. However, the most recent studies conducted by Gupta et al. [10] show that VRP has two types of mainstream studies: ones that are static and ones that are eco-friendly. The VRPSDP was first proposed by Min, et al.[11] with a case study in a public library book distribution in Franklin County, Ohio, USA. They then proposed a standard of the VRPSDP model with its objective being to minimize the total time of the route.



Key:
CVRP: Capacitated Vehicle routing problem
DCVRP: Distance-constrained vehicle routing problem
VRPB: Vehicle routing problem with backhauls
VRPTW: Vehicle routing problem with time windows
VRPPD: Vehicle routing problem with pick-up and delivering
VRPBTW: Vehicle routing problem with backhauls and time windows
VRPPDTW Vehicle routing problem with pick-up, delivering and time windows

Figure 2. Capacitated VRP

It is Dethloff [5], among all the authors, who first investigated the case from a reverse logistics point of view and built the mathematical model. He then developed the solution based on a heuristic approach. Tarantilis et al. combined a Tabu search algorithm with a local search [12]. They proposed a hybrid solution for 50 to 400 customers and claimed it produced high quality results. Tasan et al. proposed a reviewed genetic algorithm [13]. Yuchi et all explored the Tabu search with a focus on bound and computational time [14]. Most of the studies focused on producing and modifying algorithms to solve the problem.

2.3 The model of VRPSDP in RL

Dethloff [5] described the VRPSDP in RL as follows: “A given number of customers has to be serviced with a given (and assumed to be sufficiently large) fleet of vehicles of limited capacities which are usually assumed to be identical. The vehicles are stationed at a central depot to which they have to return after having finished their tour. Each of the customers requires to receive a delivery of a given size originating in the depot (forward channel) or each of the customers requires to send a pick-up of a given size to the depot (reverse channel). The task in both cases is to assign customers to vehicles and determine routes for the vehicles such that the total distance traveled is minimized“.

He then formulated a mathematical model with the objective to minimize the total travel distance by considering all of the following variables:

1. Service all customers exactly once
2. Arrive at and leave the customers with the same vehicle
3. Initial vehicle loads
4. Vehicle loads after first customer
5. Vehicle loads en-route
6. Vehicle capacity at customer and ‘en-route’
7. Sub-tour breaking constraints

It is clearly seen that there is no significant difference with what Min proposed twelve years before. However, Ernest Benedito [15] investigated the stochastic models of systems of RL. He falsified a common assumption that the quantity of products returned is independent of sales, and claimed that the hypothesis is obviously not true and can lead to suboptimal production policies. In his paper, a new sales-dependent returns model is described. In this model, the returns depend on the useful life of the products sold and on the probability of an end-of-life product being returned. A Markov decision problem is formulated in order to obtain the optimal manufacturing policy. A numerical example is provided to illustrate the use of the defined model. An approximated Markov decision model is defined where the optimal policy is easily obtained. The optimal policies of the original and the approximated models are compared.

3. Case study – drinking water supply in Jakarta

The population of Jakarta city is approximated 10 million people spread over 255.4 square miles with a density 14,464 people per km. In terms of drinking water, households in the capital city of Indonesia usually use water from different sources for different purposes, these sources being ground water and bottled/packaged water. Ground water is usually used for washing, while for drinking and cooking it is usually bought. The water for drinking is available in packaging. The size of these packages is slightly different between providers but most of them have a volume of 19 litres. The package is designed for refilling; this means that when the bottles are emptied, they should be resent directly to the depot for reloading.

Despite there being earlier attempts to address the situation, the problem remains and a RL solution is needed. There are two main issues that should be taken into account: assigning the collecting point across the city and building a collection network with a minimum distance collection cost. Collection points are assigned based on household distribution. Then, the household spread is grouped based on their geographical distance, so that one depot could be assigned to representing a group. Ideally, the depot should have a similar distance to each household in its group. The number of the group is strongly dependent on geographical conditions and the household distribution. To make it more effective, real data should be taken into account. Figure 3 shows the collection point of bottled water. Table 1 shows the delivery distance and pick-up distance for the collection points.

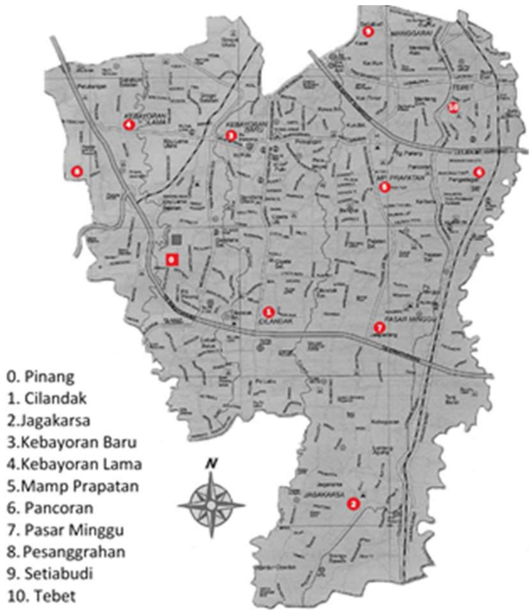


Figure 3. Collection point of bottled water (Source: Google map).

In addition, the network of delivery and pick up points is designed based on distance of the depot to each collection point (assuming that every collection point covers the same volume of demand). One of the most important things to take into account in terms of assigning the network is collection cost. The collection cost in network assignment is not always proportional to the distance of each point [5]. In typical geographical conditions, distance will be relative to the travel cost. For example, conditions of the road, traffic jams, road occupancies, etc.

4. Results

The vehicle routing has been optimized using a Tabu search. The model is assumed to be deterministic, in which the number of vehicles and the number of RLVs at each collection point are given. We assume that 3 units of trucks will travel at the same time, each having the capacity of carrying 960 bottles. The inter-node travel distance matrix is shown in Table 1.

Table 1. Inter-node travel distance matrix

Node	0	1	2	3	4	5	6	7	8	9	10
0	0	5	14	7	5	9	18	10	6	16	19
1		0	12	7	10	7	12	8	11	15	13
2			0	16	19	13	12	7	19	19	14
3				0	6	3	8	12	8	10	8
4					0	7	12	15	4	11	12
5						0	5	9	15	7	5
6							0	6	14	10	3
7								0	15	16	9
8									0	16	14
9										0	7
10											0
Delivery	0	230	350	160	330	160	190	330	250	110	210
Pick-Up	0	200	320	180	340	120	200	300	200	130	230

The results using an independent group routing is shown in Figure 4.

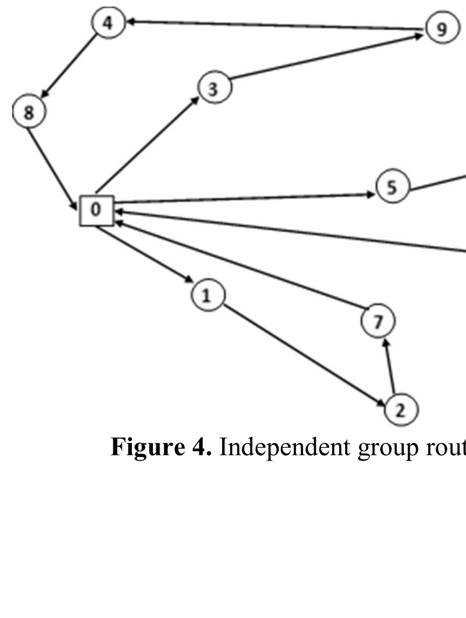


Figure 4. Independent group routing

5. Conclusion

This paper presented a tabu search method for investigating the current conditions of reverse logistics and a vehicle routing problem with simultaneous pick-up and delivery. A real case study of drinking water supply in Jakarta has been analyzed and the best routing for three independent groups has been identified. The results are promising compared with real measurement that the drivers took while travelling on the road. The idea of reverse logistics as one of the alternatives of sustainability, either in manufacturing or in the environment, will be one of the reasons why VRPSDP is still fashionable in the future.

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